REMARKS

This application has been reviewed in light of the Office Action dated September 21, 2005. Claims 1, 4, 9 and 12 have been amended to define still more clearly what Applicant regards as his invention. Claims 2, 3, 5 and 6 have been cancelled, without prejudice or disclaimer of the subject matter presented therein.

Claim 11 was objected to owing to its recitation of "Ω/square", and the specification was objected to for the same reason. The Examiner is respectfully requested to note that "Ω/square" is a well-known term in the art meaning sheet resistance (rather than the Examiner's interpretation on page 2 of the Office Action), and thus the use of that term is entirely appropriate. For example, the Examiner is referred to the attached printouts from

(1) http://ece-www.colorado.edu/~bart/book/mobility.htm,

(2) http://www.ece.gatetech.edu/research/labs/vc/theory/sheetRes.html, and

(3) http://www.four-point-probes.com/qa.html.

Page 3/4 of printout (1), page 1/2 of printout (2), and page 1/6 of printout (3) refer to "ohms per square" as being sheet resistance. Accordingly, the objection to the specification and Claim 11 is respectfully traversed, and its withdrawal requested.

Claims 1-8 and 12 were rejected under 35 U.S.C. §102(b) as being anticipated by Japanese Patent No. JP 2000-057979 (*Iguchi et al.*) (hereinafter "*Iguchi*"), and Claims 9-11 were rejected under 35 U.S.C. § 103(a) as being unpatentable over *Iguchi et al.* in view of U.S. Patent 6,617,772 (*Barton et al.*).

Without conceding the propriety of the rejection of Claims 2, 3, 5 and 6, those claims have been canceled, thereby rendering their rejection moot.

Claim 1, as amended, recites a method of manufacturing an envelope which includes a first substrate, a second substrate opposed to the first substrate, and a space defining member which is located between the first substrate and the second substrate and has a substantially plate shape. The method comprises applying a tension to the space defining member, and fixing the space defining member to the first substrate at fixing points thereon separate from each other while applying a tension to the space defining member. The method also comprises releasing the tension from the space defining member fixed to the first substrate. In the fixing of the space defining member to the first substrate, the fixing points of the space defining member to the first substrate are located between points at which the tension is exerted.

Claim 4, as amended, recites a method of manufacturing an electron beam apparatus which includes a first substrate having a plurality of electron-emitting devices on a surface thereof, a second substrate which is opposed to the first substrate and in which an electrode that controls electrons emitted from the plurality of electron-emitting devices is formed, and at least one space defining member which is located between the first substrate and the second substrate and has a substantially plate shape. The method comprises applying a tension to the space defining member, and fixing the space defining member to the first substrate at fixing points thereon separate from each other while applying a tension to the space defining member. The method also comprises releasing the tension from the

space defining member fixed to the first substrate. In the fixing of the space defining member to the first substrate, fixing points of the space defining member to the first substrate are located between points at which the tension is exerted.

Iguchi discloses that a spacer is fixed to a cathode substrate, and thereafter, a temperature of the spacer becomes the same as that of the cathode, and thereby a tension is exerted onto the spacer. Further, *Iguchi* discloses that, when the temperature of the cathode substrate is lower than that of the spacer, the spacer is fixed to the cathode substrate.

Thereafter, similar to the above, the tension will exert onto the spacer. However, nothing in *Iguchi* would teach or suggest a step of fixing a space defining member to a first substrate at fixing points thereon separate from each other while applying a tension to the space defining member, as set forth in Claims 1 and 4. Moreover, according to *Iguchi*, as described above, the difference between the thermal expansions of the spacer and the cathode based on the temperature difference is used to generate the tension exerted onto the spacer. Accordingly, the position onto which the tension exerts and the fixing position are the same. In Claims 1 and 4, on the other hand, separated fixing points fixing the space defining member to the first substrate are located between (i.e., inside) points at which the tension is exerted. Nothing in *Iguchi* would teach or suggest these features.

As such Claims 1 and 4 are believed to be clearly patentable over *Iguchi*.

The other rejected claims each depend from one or another of the

independent claims addressed above, and also are believed to be patentable, at least for the reason that each depends from a patentable base claim.

In view of the foregoing amendments and remarks, Applicants respectfully request favorable reconsideration and early passage to issue of the present application.

Applicant's undersigned attorney may be reached in our New York office by telephone at (212) 218-2100. All correspondence should continue to be directed to our below listed address.

Respectfully submitted,

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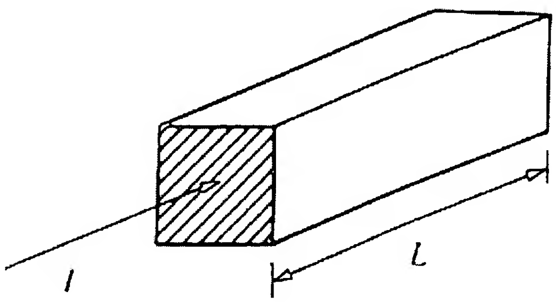
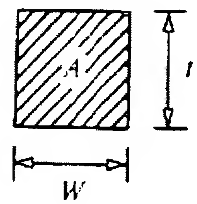
Sheet Resistance

In diffused semiconductor layers, resistivity is a strong function of depth. For circuit design, it is often convenient to work with a parameter called the "sheet resistance" (Rs).

Consider the resistance (R) of the rectangular block of uniformly doped material shown in the figure below.





$$R = \rho \frac{L}{A} \qquad \rho = \frac{1}{\sigma} \qquad \sigma = q\,(\mu_n n + \mu_p p)$$

In this sample the resistance is given by: R = Rho * L / A

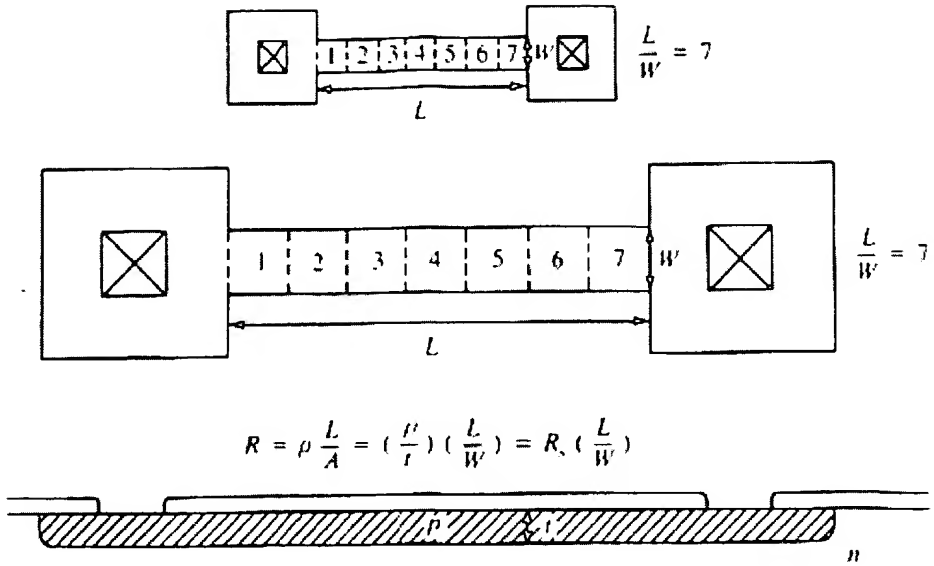
where Rho is the resistivity of the sample, and L and A are its length and cross-sectional area, respectively. If W is the width of the sample and t is its thickness (i.e. - A = Wt), then the resistance can be written:

R = (Rho/t) (L/W) = Rs (L/W)

where Rs = Rho/t is the sheet resistance of a layer of this material.

Strictly speaking, the unit for sheet resistance is the ohm (since L/W is unitless). To avoid confusion between R and Rs, however, sheet resistance is specified in unit of "ohms per square." The L/W ratio can be thought of as the number of unit squares (of any size) of material in the resistor.

Figure 2 shows the top and side views of two typical resistors with contacts at each end. The body of each resistor is 7 "squares." If the sheet resistance of these diffused resistors were 50 ohms/square, then the body of each (not including the contacts) would have a resistance of 350 ohms.



Sheet resistance is measured by a 4-point probe. A geometric correction factor (CF) is usually required to convert the voltage/current ratio measured by the 4-point probe into sheet resistance. This correction factor accounts for the sample size, shape and probe spacings. The sheet resistance measure by the probe is given by:

Rs = (V/I) * CF

where V is the measured DC voltage across the two voltage probes and I is the DC current passing through the two current probes. The value of CF for samples of various sizes and shapes can usually be found in a reference book.

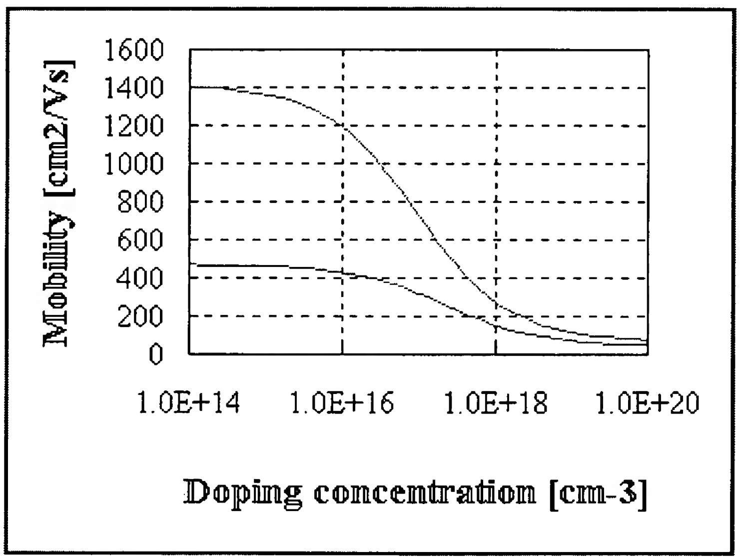
2.9 Mobility - Resistivity - Sheet Resistance

Table of Contents - Glossary - Study Aids - ← →

In this section:

2.9.1 Bulk mobility

The mobility of electrons and holes in bulk silicon is shown in the figure below.



resistiv.xls - mobility.gif

Fig.2.9.1 *Electron and hole mobility versus doping density for silicon*

This is an active figure which can be used to find the bulk mobility for specific doping concentrations as well as the related resisitivity and sheet resistance.

Note that the mobility is linked to the **total** number of ionized impurities or the sum of the donor and acceptor rather than the free carrier density which is to first order related to the difference between the donor and acceptor concentration.

The minority carrier mobility also depends on the total impurity density, using the curve which corresponds to the minority carrier type. The curves are calculated from the empiric expression:

$$\mu = \mu_{\min} + \frac{\mu_{\max} - \mu_{\min}}{1 + (\frac{N}{N_r})^{\alpha}}$$ (mob10)

where μ_{min}, μ_{max}, α and N_r are fit parameters. These parameters for Arsenic, Phosphorous and Boron doped silicon are provided in the table below:

	Arsenic	Phosphorus	Boron
μ_{min} (cm^2/Vs)	52.2	68.5	44.9
μ_{max} (cm^2/Vs)	1417	1414	470.5
N_r (cm^{-3})	$9.68\ 10^{16}$	$9.20\ 10^{16}$	$2.23\ 10^{17}$
α	0.68	0.711	0.719

tmob1.gif

Example 006

2.9.1.1 Temperature dependence of the mobility

2.9.2 Resistivity

The conductivity of a material is defined to be the current density divided by the applied electric field. Since the current density equals the product of the charge of the mobile carriers, their density and velocity it can be expressed as a function of the electric field using the mobility. To include the contribution of electrons as well as holes to the conductivity, we add the current density due to holes to that of the electrons, or:

$$J = q\, n\, v_e + q\, p\, v_h = q(n\, \mu_n + p\, \mu_p)\mathcal{E}$$ (mob8)

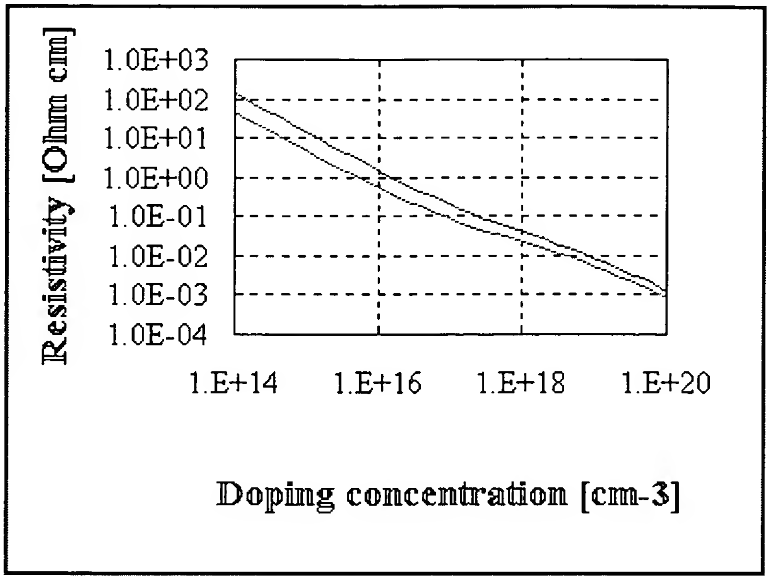
The conductivity due to electrons and holes is then obtained from:

$$\sigma \overset{\Delta}{=} \frac{J}{\mathcal{E}} = q\,(n\,\mu_n + p\,\mu_p)$$ (mob9)

The resistivity is defined as the inverse of the conductivity, namely:

$$\rho = \frac{1}{\sigma} = \frac{1}{q\,(\mu_n n + \mu_p p)}$$ (mob5)

The resulting resistivity as calculated with the expression above is shown in the figure below:



resistiv.xls - resistiv.gif

Fig.2.9.2 *Resistivity of n-type (red curve) and p-type (blue curve) silicon versus doping density*

Example 003 - Example 004

2.9.3 Sheet resistivity of a 14 mil thick wafer

The concept of sheet resistance is used the characterize both wafers as thin doped layers, since it is typically easier to measure the sheet resistance rather than the resistivity of the material. The sheet resistance of a layer with resisitivity, ρ, and thickness, t, is given by their ratio:

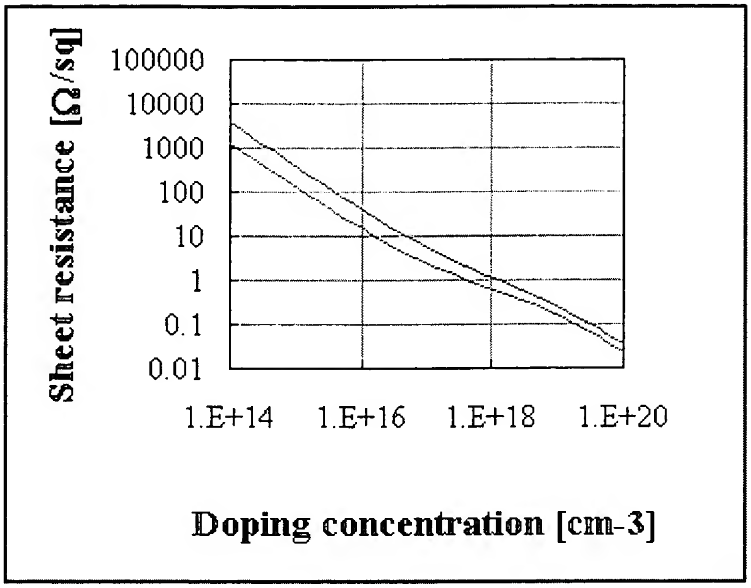
$$R_S = \frac{\rho}{t} \quad \text{(mob7)}$$

While strictly speaking the units of the sheet resistance is Ohms, one refers to it as being in Ohms per square. This nomenclature comes in handy when the resistance of a rectangular piece of material with length, L, and width W must be obtained. It equals the product of the sheet resistance and the number of squares or:

$$R = R_S \frac{W}{L} \quad \text{(mob6)}$$

where the number of squares equals the length divided by the width.

The figure below shows the sheet resistance of a 14 mil thick silicon wafer which is n-type (blue curve) or p-type (red curve)



resistiv.xls - sheetres.gif

Fig.2.9.3 *Sheet resistivity of a 14 mil thick n-type (red curve) and p-type (blue curve) silicon wafer doping density. This active figure can be modified to accomodate any layer thickness.*

2.8 ← → 2.10

BRIDGE Technology

FOUR-POINT-PROBES HOME

Four-Point-Probes

Questions and Answers Regarding Resistivity, Resistance, Surface Resistivity, Sheet Resistance and Volume Resistivity

by John Clark, C. Eng, M.I.Mech.E., F.B.H.I., Managing Director of Jandel Engineering Ltd.

The following comments are based on elementary physics (before semiconductors!) and some years measuring semiconductors and thin films. They are my opinion only, but don't get criticised in practice!

* * *

Q. I would like to know why using a four point probe you don't have trouble with contact resistances; using two current injection probes and two voltage probes, the voltage probes still probe the voltage through a Schottky barrier (for metal probes on an semiconductor), so they still 'see' the voltage drop through this barrier. So, could you tell me where I am wrong?

A. The very reason for "four point" probe measurements is to divorce the probes supplying the current from the probes measuring the voltage, so it is only necessary to consider the "voltage probes". The device used to measure the voltage is provided with a very high input impedance (ASTM F84 recommends at least 10^6 x the resistivity of the specimen), thus the contact resistance is a small proportion of the resistance in the voltage measuring circuit. Compound semiconductors have relatively large contact resistance, and unless heavily doped are not measurable with a normal DC 4- point probe measuring system. The pressure of the 4-point probe needles invariably damages the crystal structure beneath the needles. We suppose that such damage promotes ohmic contact by largely eliminating the rectifying diodes you mentioned.

* * *

Q. Is there a difference between sheet resistance and sheet resistivity? At least one author claims there is.

A. This is loose thinking. Sheet resistance is measured in ohms per square while any kind of resistivity is measured in ohms.cm or ohm.metre. I believe the two expressions are synonymous.

*   *   *

Q. Is sheet resistance/resistivity an "inherent" property of a material, or is it a function of thickness?

A. RESISTIVITY is the inherent property of the material which gives it electrical resistance. It is sometimes called Specific Resistance. Sheet resistance is the resistance of a thin sheet of material which when multiplied by the thickness (in cm) gives the value of resistivity.

*   *   *

Q. At least one author claims that "surface resistivity is a more precise measurement when dealing with insulating or slightly conductive materials; the problem with evaluating surface resistivity in highly conductive materials is the underlying assumption that electrons move from the negative electrode across the top surface of the conductive layer only to the positive layer." In other words, he seems to be implying that "you can't measure surface resistivity on highly conductive materials." True?

True.

*   *   *

Q. Another author seems to back up #3: "Except in theory, there is no such thing as surface resistivity. Physics handbooks list surface resistivity values for dielectrics (no values below 108W/square), but no surface resistivity values are listed for conductive materials. Volume resistivity values are given for both insulators and conductors. "Insulators have very thin (i.e., several molecular layers thick) conductive surfaces; but the surface conductivity of a conductor's surface is indistinguishable from its volume conductivity. On an insulative substrate such as sapphire, a thin conductive conductive film has a surface resistivity related to its thickness. Generally, one should not assume that surface and volume resistivities are related." I find this very interesting. He's basically saying that an insulator really has a thin conductive layer, and that it is possible to measure it's resistivity, but it is not possible to measure surface resistivity of a conductor.

A. Surface resistivity - this is a different animal which I am not clear about. As far as I know it can't be measured with a four point probe. It seems to be done with conductive electrodes pressed onto the specimen and a high voltage applied when the current which flows is measured. I believe ASTM D-991-89 or IEC 93 are applicable. It usually seems related to insulators and I have no experience of this kind of measurement. According to my book of "Tables of Physical and Chemical Constants" (Kaye and Laby) Surface Resistivity is defined as the resistance between opposite edges of a square, and the unit is the ohm (per square). The tables give a figure for various materials after a period of one minute of application of the measurement voltage. This is

because the insulator becomes charged.

* * *

Q. You seem to be stating that there is a difference between "sheet" resistance and "surface" resistance. I wasn't aware of this, which is probably why I've been so confused! So is it true there is a distinction between the two?

A. I think that "surface resistance" relates principally to insulators as I remarked previously. I have some more information from Keithley Instruments - see their application note # 314 (volume_surface.pdf) 483KPFD file which refers additionally to ASTM D-257.

Additional Notation: Many surface resistivity instruments are relatively low cost, low accuracy instruments designed to measure resistivities in the range from 10^4 to 10^13 ohms-per-square and are used on materials such as ESD packaging, bags, etc. Accuracy of about 1 decade is typically achievable. These systems will have either a contacting ring with one probe in the center, or three probes in a triangle arrangement with a fourth probe in the center. The probes are made of conductive rubber. Bridge Technology does not offer instrumentation for making surface resistivity measurements. Technical information about surface resistivity measurements can be read about here: http://www.esdjournal.com/techpapr/ohms.htm

* * *

Q. Let's say I have a sample that's infinite in 3 dimensions, and I use a 4-point probe measures resistance. Will the resistance be independent of probe spacing? The equations seem to imply this.

A. Such a sample is usually defined as a "semi-infinite volume" if it extends to infinity in all directions below a plane on which four probes are located.
For equidistant probes:
Resistivity = 2 x pi x s x (V/I)
where s is the probe spacing in cm.

Compare this with a "thin" sample when
Resistivity (rho) = pi/(logn2) x V/I x t
where t is the thickness and
pi/(logn2) x V/I
is the sheet resistance.
Hence it can be seen that the formula is independent of spacing.

* * *

Q. As you stated, the equation for volume resistivity of a "semi-infinite volume" is:

Resistivity = 2 x pi x s x (V/I)

where s is the (equidistant) probe spacing in cm.

For a homogenous material, the resistivity is constant, correct? Thus no matter what the probe spacing is, and no matter what the measured resistance value is (V/I), the resistivity value should always be the same, correct?

Rearranging the equation, you have:

resistivity/(2*pi) = s * (V/I)

The left-hand portion should be constant for a homogenous material, regardless of s or resistance value.

This implies the probe spacing and the resistance (V/I) are inversely proportional; if s is decreased, the measured resistance (V/I) must increase, and if s is increased, the measured resistance (V/I) must decrease. Is this correct? But it would seem as if the *opposite* would happen, i.e. as s is increased, the resistance (V/I) would increase.

A. Your argument about s and V/I must be valid. Although one might suppose that a larger spacing on the sample might result in a larger voltage drop, in practice it doesn't work that way.

*   *   *

Q. Do you have any papers that explain all of this?

A. The earliest paper is by LB Valdes
Proc IRE Feb 1954 "Resistivity Measurements on Germanium for Transistors" -
pages 420-427.

There are a host of others, principally concerned with correction factors for special cases.

a) Linear Array Probes

Circular wafers at centre:
1. D. E. Vaughan, Br.J. Appl. Phys., 12, 414 (1961)
2. M. A. Logan, Bell Sys. Tech. J., 40, 885 (1961)
Off centre but on radius:
3. L. J. Swartzendruber, National Bureau of Standards Technical Note 199
(1964)
Perpendicular to radius:
4. M. P. Albert and J. F. Combs, IEEE Trans. Electron Devices, ED-11, 148

(1964)
5. L. J. Swartzendruber, Solid State Electronics, 7, 413 (1964)
Rectangular sample at centre and off centre:
6. M. A. Logan, Bell Sys. Tech. J., 46, 2277 (1967)
Half cylinder:
7. E. B. Hansen, Appl. Sci. Res., 8B, 93 (1960)
Circular rod:
8. H. H. Gegenwarth, Solid State Electronics, 11, 787 (1968)
Rectangular bar:
9. A. Marcus and J. J. Oberly, IEEE Trans. Electron. Devices, ED-3, 161 (1956)

Note: All the foregoing is based on measurement using a four point linear probe, the current being passed between the outer probes and the voltage measured across the inner two probes.

b) Square Array Probes

Small slice at centre:
as 9 above
Small slice along a radius:
as 3 above
Square sample:
10. M. G. Buehler, Solid State Electronics, 10, 801 (1967)
Thick sample near boundary:
11. S. B. Catalano, IEEE Trans. Electron. Devices, ED-10, 185 (1963)
thin infinite sheet:
as 10 above

Note: Square array probes have the current passed between two adjacent probes and the voltage measured across the two opposite when used for resistivity measurement.

Best Regards

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